MONITORING OF CORROSION OF PIPELINES OF COOLING SYSTEM OF AUTOMOBILE GAS-FILLING COMPRESSOR STATIONS

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Analysis of peculiarities of corrosion processes was made in carbon steel and its welded joints in cooling liquids of TOSOL type used in cooling systems of automobile gas-filling compressor stations (AGFCS). A method of monitoring the instant rate of corrosion in metal of pipes and welded joints in the cooling system at AGFCS, based on the method of polarization resistance, is offered. Sensors have been developed for estimation of corrosion rate in carbon steel and its welded joints in cooling liquid.

Keywords: *carbon steels, welded joints, automobile gas-filling compressor stations, cooling liquids, corrosion rate, method of mass measurement, method of polarization resistance, corrosion monitoring*

The present work is aimed at the investigation of a feasibility of continuous monitoring of kinetic change in corrosion rate of carbon steel and its welded joints in the cooling liquids (CL), being studied, using a method of polarization resistance.

As the practice shows, the CL becomes corrosion-active after one or two years of service due to oxidation of ethylene glycol, impurity wastes and contamination of CL itself with iron oxides. In this connection, the CL in cooling system of automobile gas-filling compressor stations (AGFCS) needs the periodic replacement or correction. Using sensors it is possible to define the time moment, when CL becomes corrosion-active with respect to pipe metal and its welded joints. Welded joints in cooling systems of AGFCS are subjected to the largest corrosion wear. Therefore, the analysis of specifics of corrosion processes was made on welded joints of carbon steel in CL of TOSOL type used in cooling systems of AGFCS. The effect of CL composition on kinetics of corrosion of carbon steel at room temperature was studied. The investigation of electrochemical characteristics of CL samples was carried out under laboratory conditions at room temperature. The methods of mass measurement, polarization resistance, polarization curves were used in the work.

It was established as a result of carried out investigations that the instant rate of corrosion of metal of pipes and their welded joints in the cooling system of AGFCS can be monitored during long time using the method of polarization resistance. The developed method allows determining the instant rate of corrosion of metal of pipes and their welded joints in the cooling system at AGFCS.

At present, the physical-chemical and protective properties of CL, used at AGFCS, are subjected to monitoring for compliance with requirements of GOST 28084–89 [1] by the following characteristics: appearance, density, temperature of crystallization beginning, hydrogen factor pH, alkalinity, corrosion effect on metals, including steel. Evaluation of corrosion effect on metals, envisaged by GOST 28084–89, is performed using the method of mass measurement, which is labor-consuming and long-time as the tests are performed during 336 h (14 days). Besides, the rates of corrosion, determined by the method of mass measurement, represent the integral characteristic averaged with time.

The following CL were selected for investigation: TOSOL (solution of ethylene glycol $HOCH_2CH_2OH$ with impurities in water), ethylene glycol ($HOCH_2CH_2OH$, molar mass of 62.07), propylene glycol ($CH_3CHOHCH_2OH$, molar mass of 76.09), and also standard media (3 % solution of NaCl and distilled water H_2O).

Physical-chemical and corrosion properties of CL were evaluated for compliance with requirements of

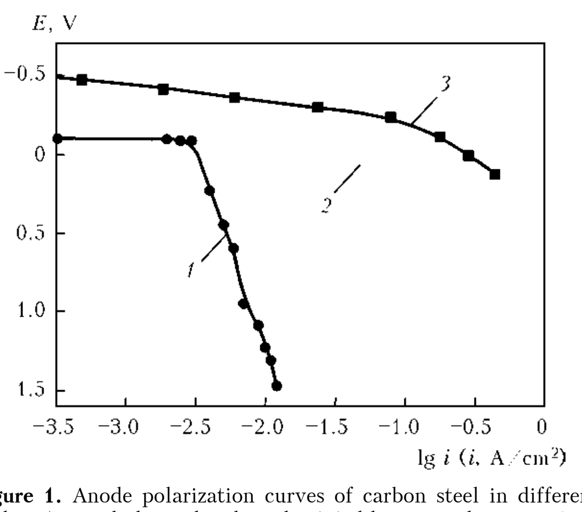

Figure 1. Anode polarization curves of carbon steel in different media: *1* — ethylene glycol in the 1:1 dilution with water; *2* — propylene glycol in the 1:1 dilution with water; *3* — 3 % solution of NaCl

Physical-chemical and protective properties of CL

Characteristic (parameter, property)	Standard acc. to GOST 28084–89		Test media				
				Ethylene glycol		Propylene glycol	
	CL-K	CL-40	TOSOL	Concentrated	In dilution with water (1:1)	Concentrated	In dilution with water (1:1)
Appearance	Transparent homogeneous liquid without mechanical inpurities						
Density, g/cm^3	1.100–1.150	1.065–1.085	1.056	1.114	1.075	1.036	1.036
Temperature of crystallization beginning, °C, not higher than	–35 in 1:1 dilution	–40	–40	–13	–38	–60	–36
Hydrogen factor (pH)	7.5–11.0	7.5–11.0	8.7	5.1	5.1	7.2	7.2
Alkalinity, cm^3, not less than	10	10	9.196	0.05	–	0.05	–
Corrosion effect on steel, g/(m^2·year), not more than	0.0041	0.0041	0.0008	0.00128	0.0056	0.00163	0.0048
Electric conductivity, S/m	–	–	0.2272	$8.364 \cdot 10^{-5}$	0.0845	$3.182 \cdot 10^{-5}$	0.073

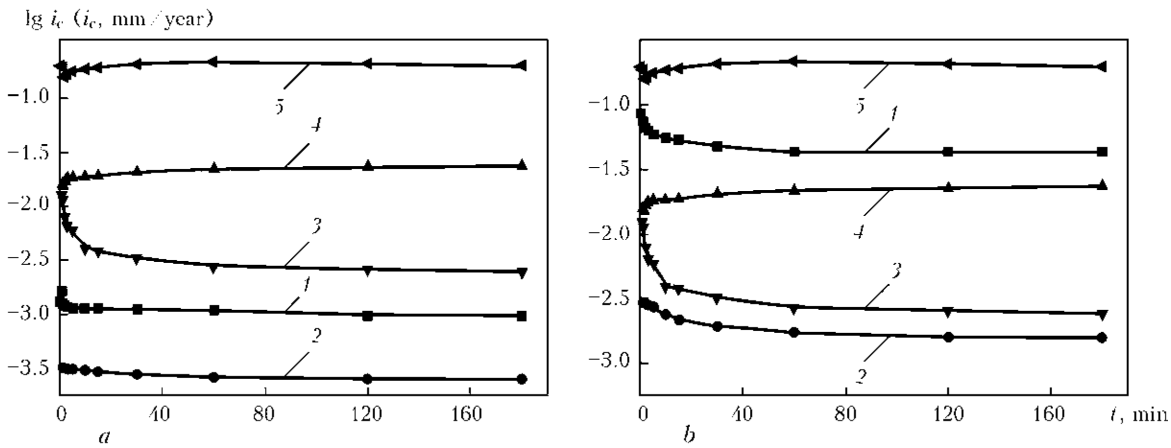

Figure 2. Kinetics of corrosion of carbon steel in concentrated (*a*) and diluted CL (*b*): *1* — ethylene glycol (1:1); *2* — propylene glycol (1:1); *3* — TOSOL; *4* — H_2O; *5* — 3 % solution of NaCl

GOST 28084–89. Results of tests of physical-chemical and protective properties of investigated CL and standard media are given in the Table.

Measurement of rates of carbon steel corrosion by the method of polarization resistance was made using the system of corrosion monitoring SKMT (TU V 33.2-01181535-014:2005) in CL, standard solution of 3 % sodium chloride and distilled water at room temperature. The rate of corrosion was calculated by formula

$$i_c = \frac{2B}{S}\frac{\Delta I}{\Delta E},$$

where B is the constant of medium, mm/(year·Ohm··cm^2); ΔI is the current, measured by the system of corrosion monitoring of SKMT type, A; S is the specimen surface area, cm^2; ΔE is the potential shifting per 10 mV.

From the data of work [2] the electrochemical processes in CL are proceeding under the conditions of passivation or diffusion control. The constant B was specified for CL and water neutral media.

CL of TOSOL type contains ethylene glycol, water and impurities, delaying the process of corrosion. To define the particular stage of monitoring the process of corrosion of steel in CL, the anode polarization curves were taken both in CL and in 3 % solution of NaCl (Figure 1). It follows after their analysis that potential of corrosion of carbon steel in CL is shifted to the region of more positive values as compared with

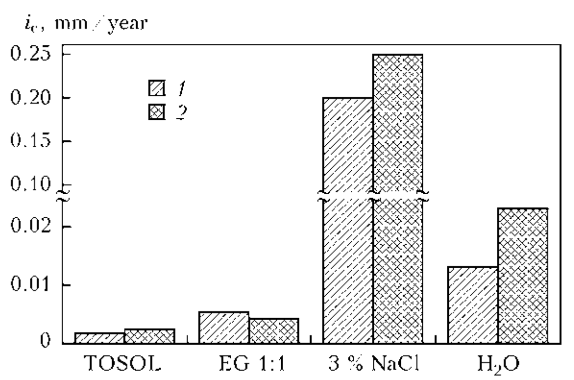

Figure 3. Diagrams of rates of corrosion of carbon steel in different media obtained by the method of mass measurement (*1*) and polarization resistance (*2*)

that in 3 % solution of NaCl. The path of curves proves the passivation of steel surface in CL as a result of delaying of anode processes, i.e. increase of slopes of anode polarization curves in propylene glycol and ethylene glycol as compared with 3 % solution of NaCl indicates the difficulty of anode reaction proceeding on the metal surface.

Kinetics of corrosion of carbon steel in concentrated and diluted CL, studied using the method of polarization resistance, is presented in Figure 2. It occurred that among the concentrated CL the TOSOL is the most aggressive for the carbon steel, and the propylene glycol is aggressive to the lowest degree. Ethylene glycol occupies the intermediate position. Results of measurement of corrosion rate in diluted CL have a good correlation with polarization curves given in Figure 1.

Ratio of rates of corrosion of carbon steels, obtained by the method of polarization resistance and method of mass measurement in different media, are given in Figure 3. It was established that the rates of corrosion, determined by the method of polarization in different media, coincide.

Thus, the application of method of polarization resistance for continuous monitoring the kinetics of changing the rate of corrosion of carbon steels and their welded joints is completely admissible.

1. *GOST 28084–89*: Cooling low-freezing liquids. General specifications. Introd. 01.07.90.
2. Chviruk, V.P., Polyakov, S.G., Gerasimenko, Yu.S. (2007) *Electrochemical monitoring of technogeneous media*. Kyiv: Akademperiodika.

DEVELOPED AT PWI

STRENGTHENING OF PRESS-STAMPING TOOLING COMPONENTS BY THE METHOD OF CARBIDE COATING DEPOSITION FROM A SALT MELT

PWI developed the technology of deposition of wear-resistant coating from vanadium and chromium carbides on the surface of products from iron-carbon alloys (steels, cast iron). Hardness of vanadium carbide coatings is equal to 26–28 GPa, those of chromium carbide to 16–18 GPa. Coating thickness is in the range of 5–40 μm, depending on the composition of steel, carbide type and deposition conditions. The main requirement to steel composition is carbon concentration in the surface layer (not less than 0.6 % in the case of vanadium carbide, and 0.35 % for chromium carbide).

The process of coating formation consists in part immersion into a salt melt, heated up to 850–1050 °C, with soaking for 0.5–3.0 h, and it allows combining the process of coating deposition with no-oxidation heating of the product for quenching. Conditions of cooling of a coated part (in water or oil) and subsequent tempering operations depend on the requirements to heat treatment of its base material. Final stage consists in washing the part surface in hot water to remove the remains of the salt melt. Surface roughness of coated steel is not impaired, if in the initial condition $R_a \geq 0.5$ μm.

Technology features a high environmental safety does not generate any toxic drained wastes or gas emissions, and can be realized under the conditions of a standard heat treatment section with the availability of a shaft furnace with working temperature of 1000–1200 °C.

Parts with the carbide coating can be operated at temperatures of up to 400 °C in the case of vanadium carbide, and up to 850 °C in the case of chromium carbide.

Experience of practical application of this technology showed that the high hardness of the carbide layer ensures an extension of press-stamping tooling life by 3 to 50 times, depending on the tool steel grade and conditions of tool operation.

An additional advantage of vanadium carbide coating is lowering of the coefficient of friction and ability to conduct the stamping process without lubrication due to that.

Developed technology will become applied in strengthening of press-stamping, cutting, bending, drawing and blade tools, as well as parts of machines and equipment, operating under the conditions of friction and wear, in particular at application of shock loads.

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